Towards Real-Time Detection of Meteorological Tsunami-Generated Ionospheric Disturbances Using Stand-Alone GNSS Receivers

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Outline

Objectives

Study the ionospheric response to meteotsunami event
Separate contribution of mesoscale convective system and meteotsunami

Introduction

Introduction to meteotsunami event system
Introduction to tsunami-induced TIDs detection from the ionosphere

Methodology

Details of the VARION algorithm
Details of the WP-GITM model

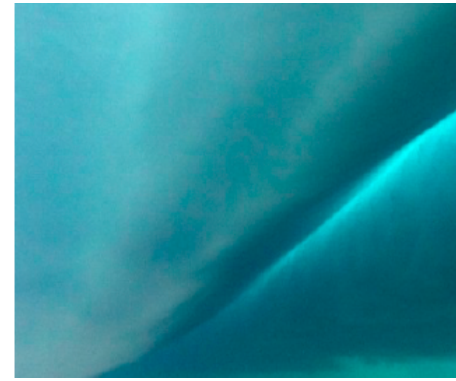
Results

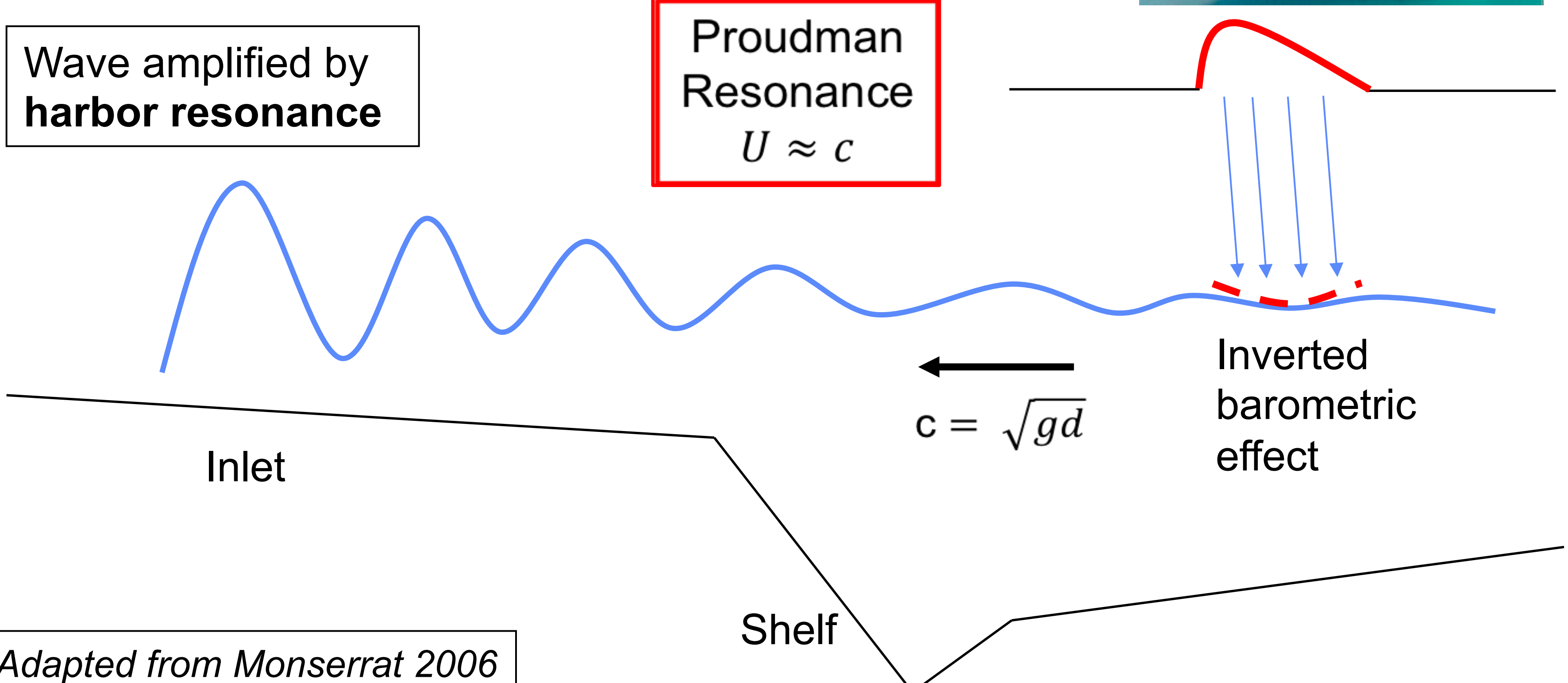
Atlantic Meteotsunami – Jun 13, 2013 event

Conclusions and Prospects

Introduction - Meteotsunami

Weather system is the **tsunami source**





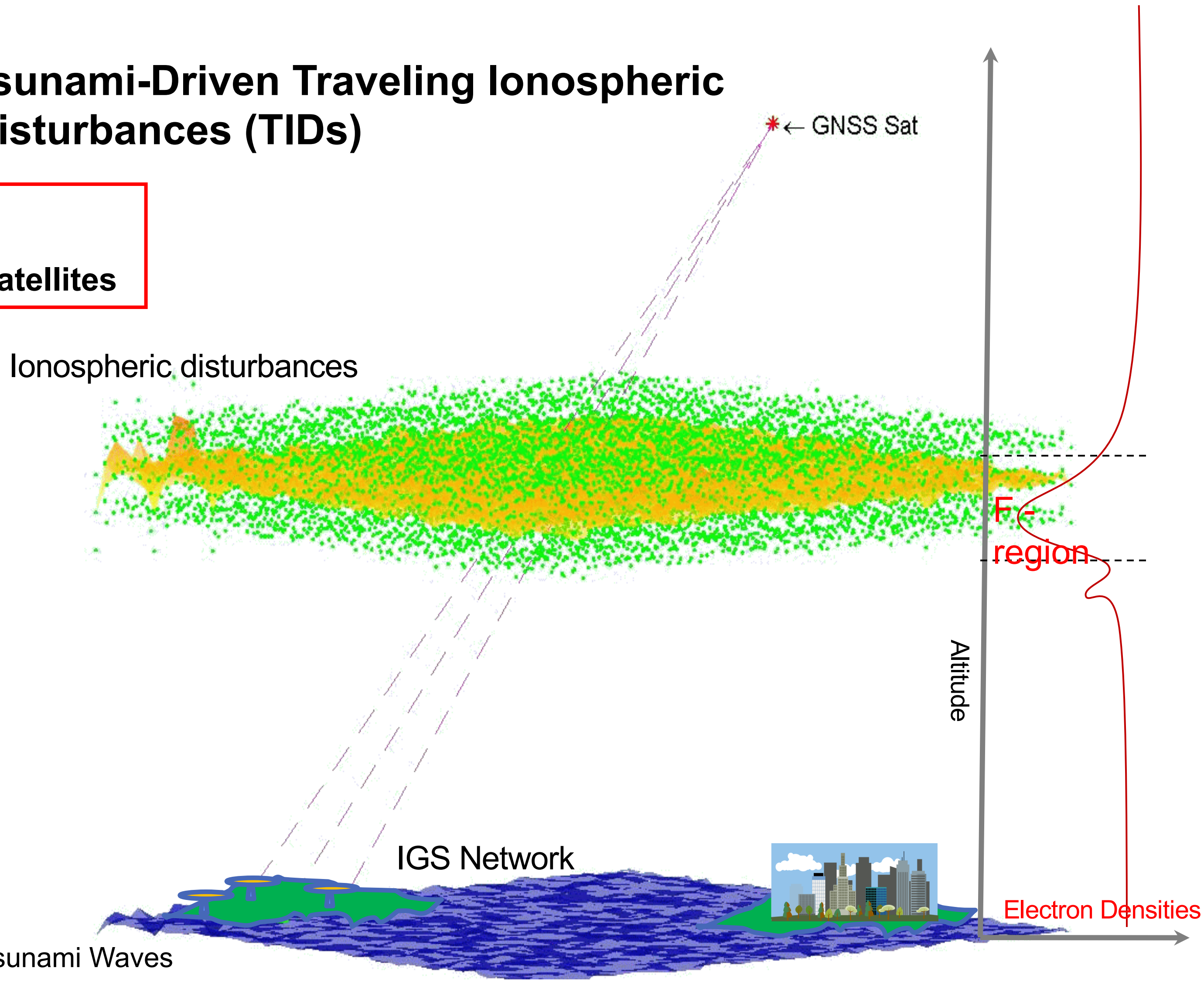
Adapted from Monserrat 2006

Introduction

Tsunami-Driven Traveling Ionospheric Disturbances (TIDs)

Tsunamis produce **TIDs**

TIDs detectable with **GNSS Satellites**



Credits to Y.-M. Yang

Methodology- VARION

Methodology

- Variation of sTEC
  - **Dual-frequency phase** observations (1s, 15s, 30s)
  - **Geometry-free combination** to remove geometry, clocks and all **non-dispersive effects**
  - **Time single differences** of geometry-free observations (**phase ambiguity** removed as for **IFB**, assuming a constant for a given period)
  - **Cycle slips** can be detected as **outliers**
- Total sTEC perturbation
  - **Integration** of sTEC variations

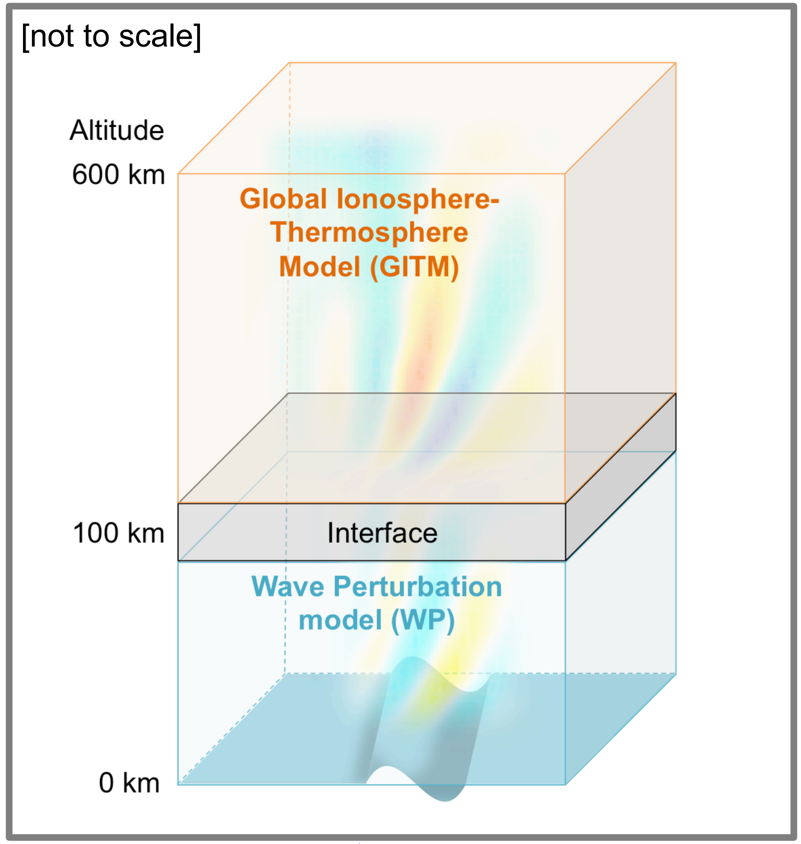
Real-Time sTEC solutions for TIDs detection

Savastano et al., 2017

Methodology- WP-GITM

Input I
solar wind conditions, solar irradiance, auroral particle precipitation

For Tsunamis



Output
Ionospheric and thermospheric disturbances

Input II
Tsunami wave characteristics (amplitude, direction, period, speed)

Meng et al., 2015

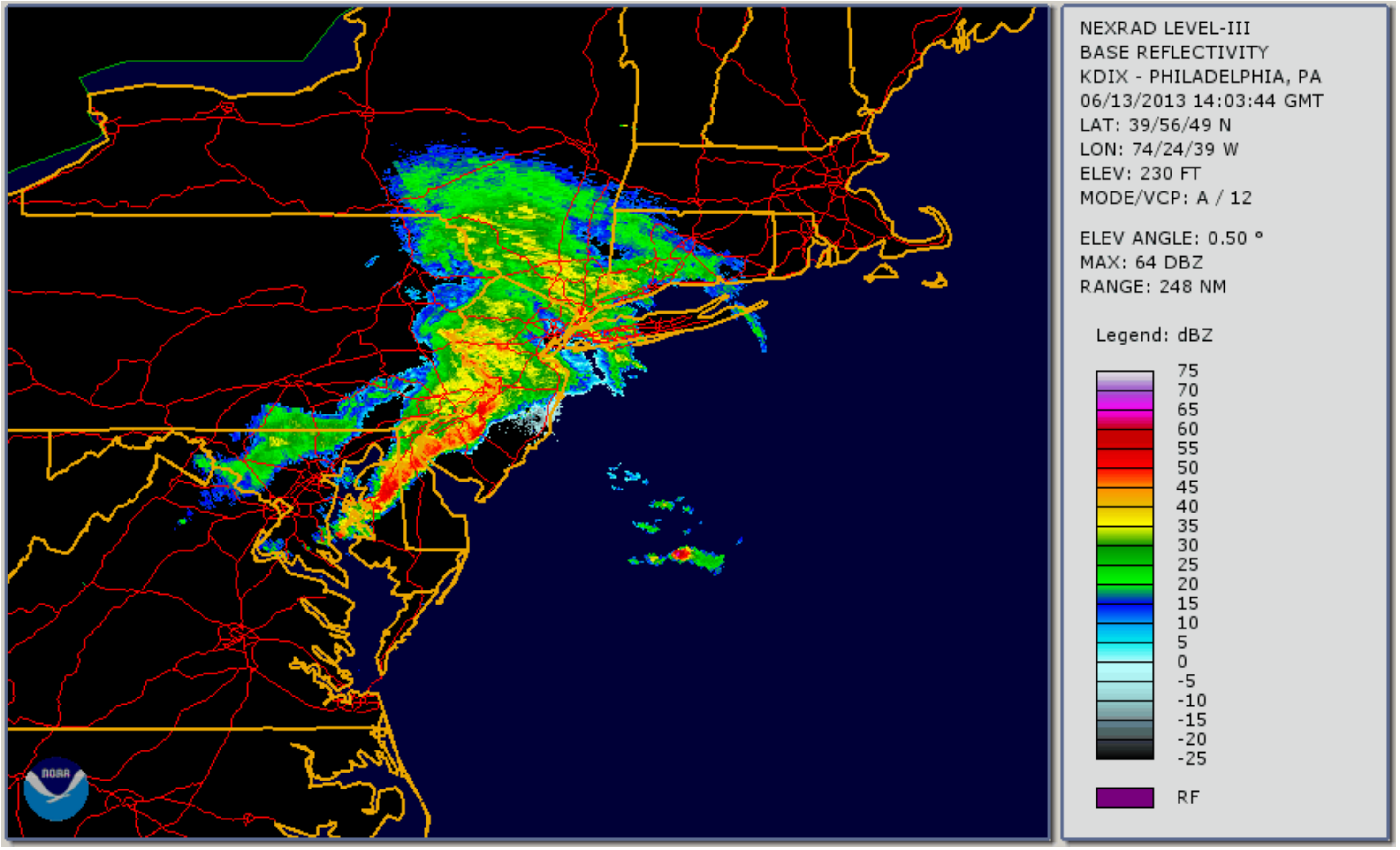
Results

Ionospheric Response to The 2013 Meteotsunami Event

- Event date: **13 June 2013**, 18:50 UTC
- Area affected: **U.S. Atlantic Coast**
- Tsunami source: **Mesoscale Convective System (MCS)**
- Damages: **economical** and several **injures**

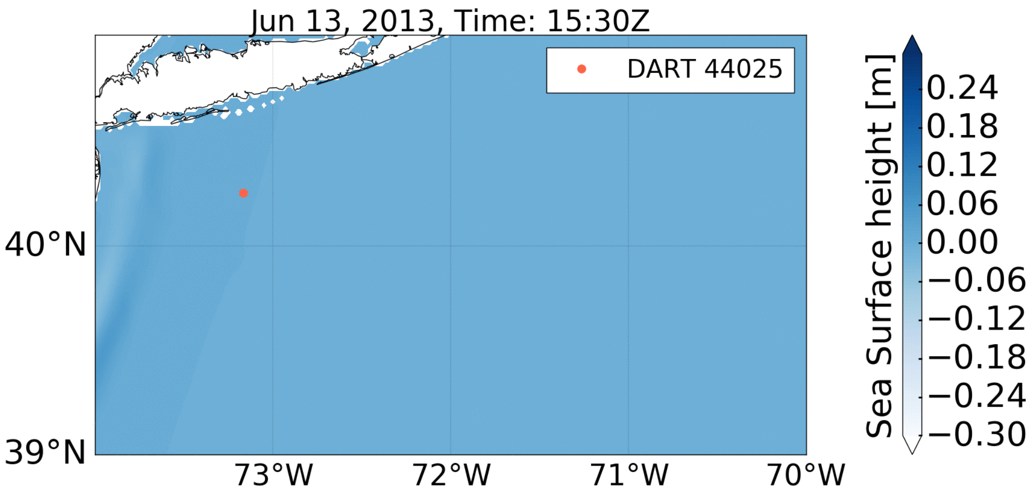
Mesoscale Convective System

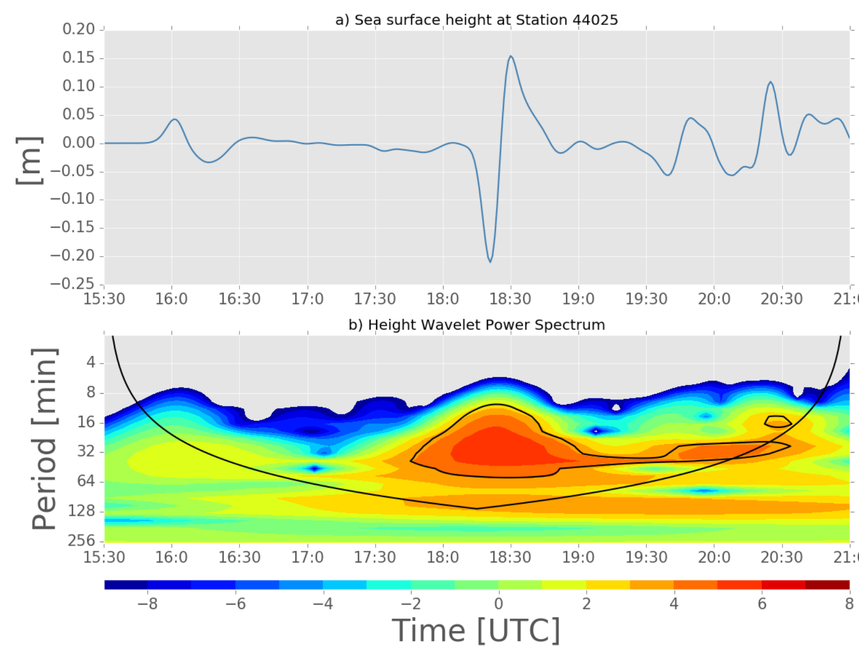
- **Weather system** moving offshore was the **tsunami source**
- **Storm speed = wave speed**: Proudman resonance



NOAA PTWC RIFT Model

- Atlantic shelf break **reflected back** the waves towards U.S. East Coast





Tsunami wave characteristics:

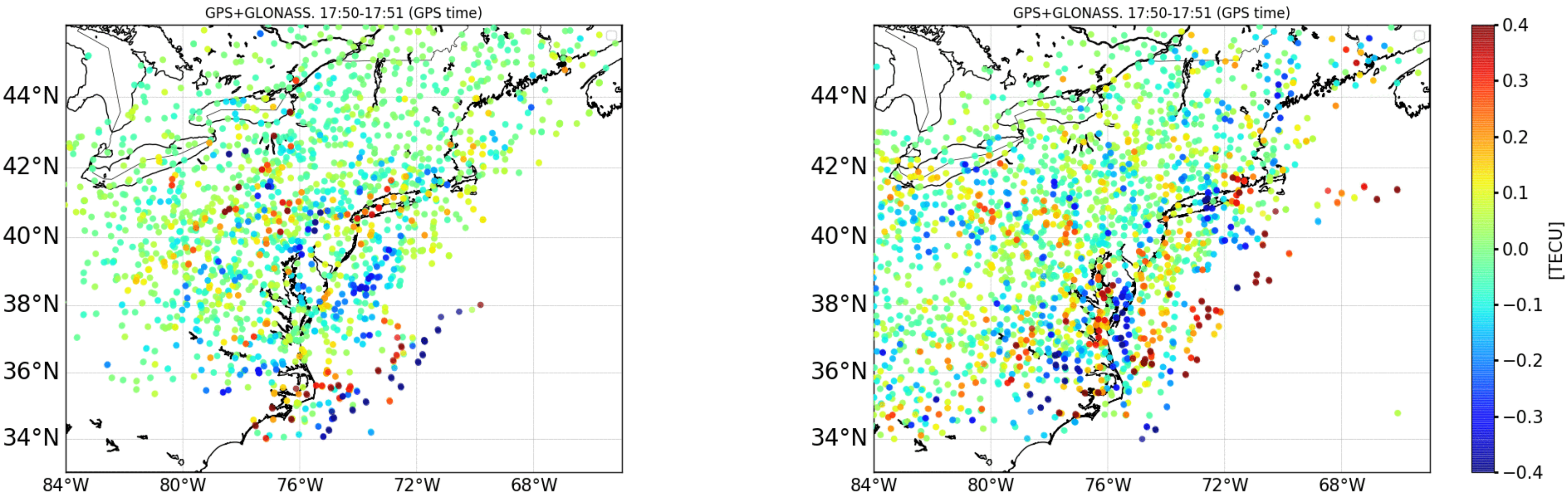
- **Amplitude** = 20 cm
- **Period** = 20 min
- **Speed** = 30 m/s
- **Direction** = 120˚ East

VARION Results

- **GPS+GLONASS** constellations
- Cut-off elevation angle: 30 degree

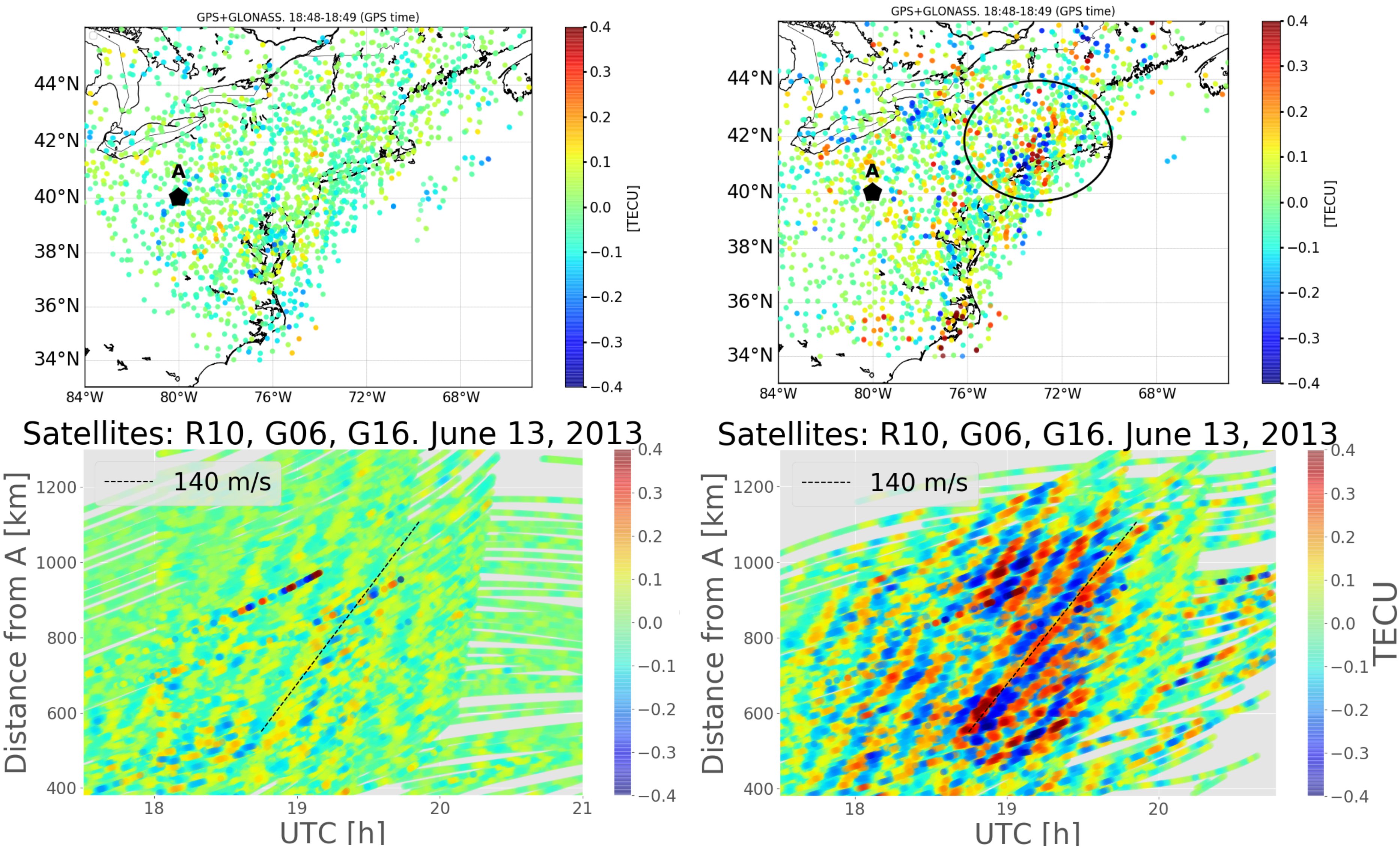
- **Day Before**: 12 June, 2013

- **Day Event**: 13 June, 2013

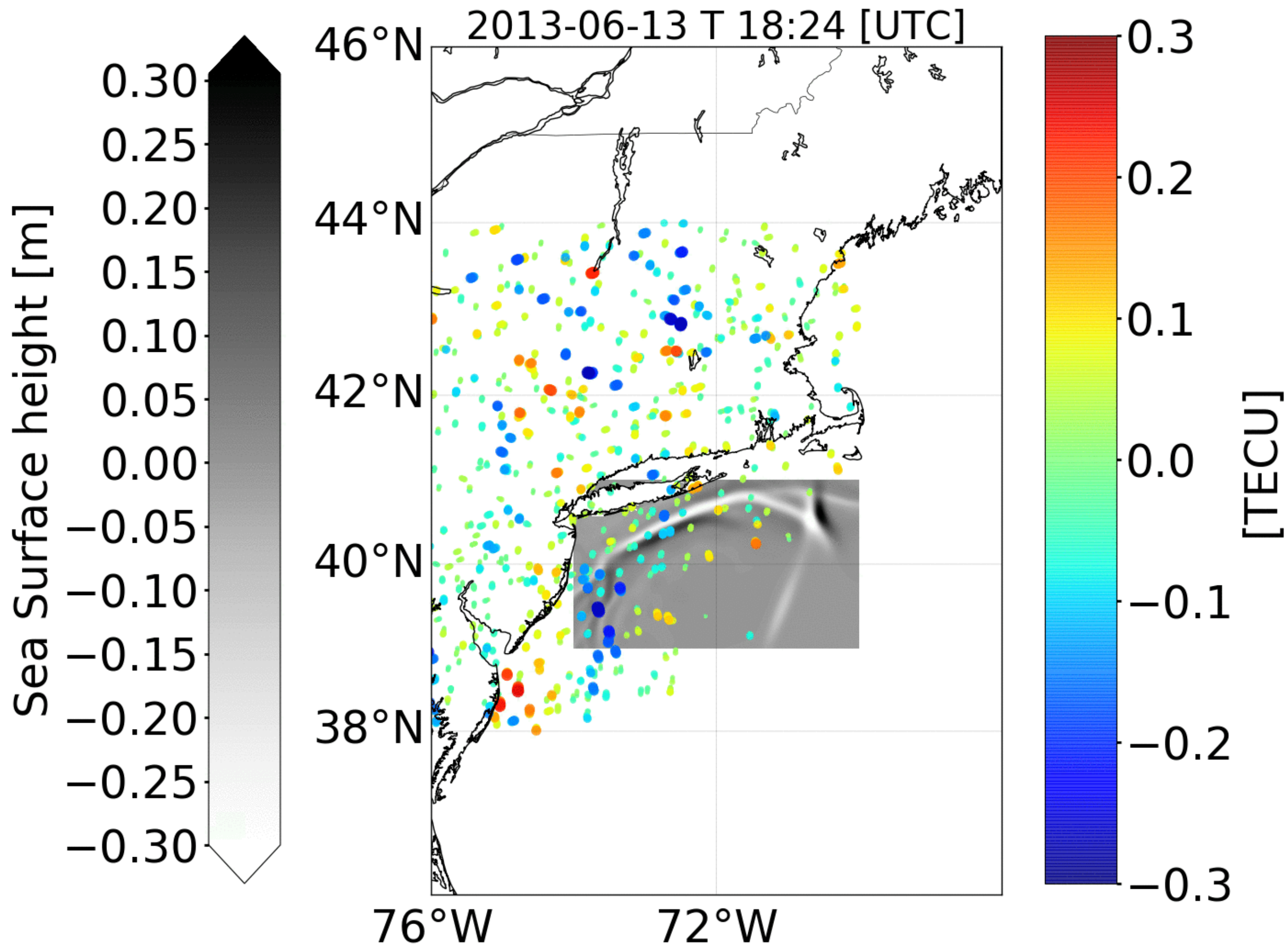


TIDs detected during the MCS+Meteotsunami event

VARION Results

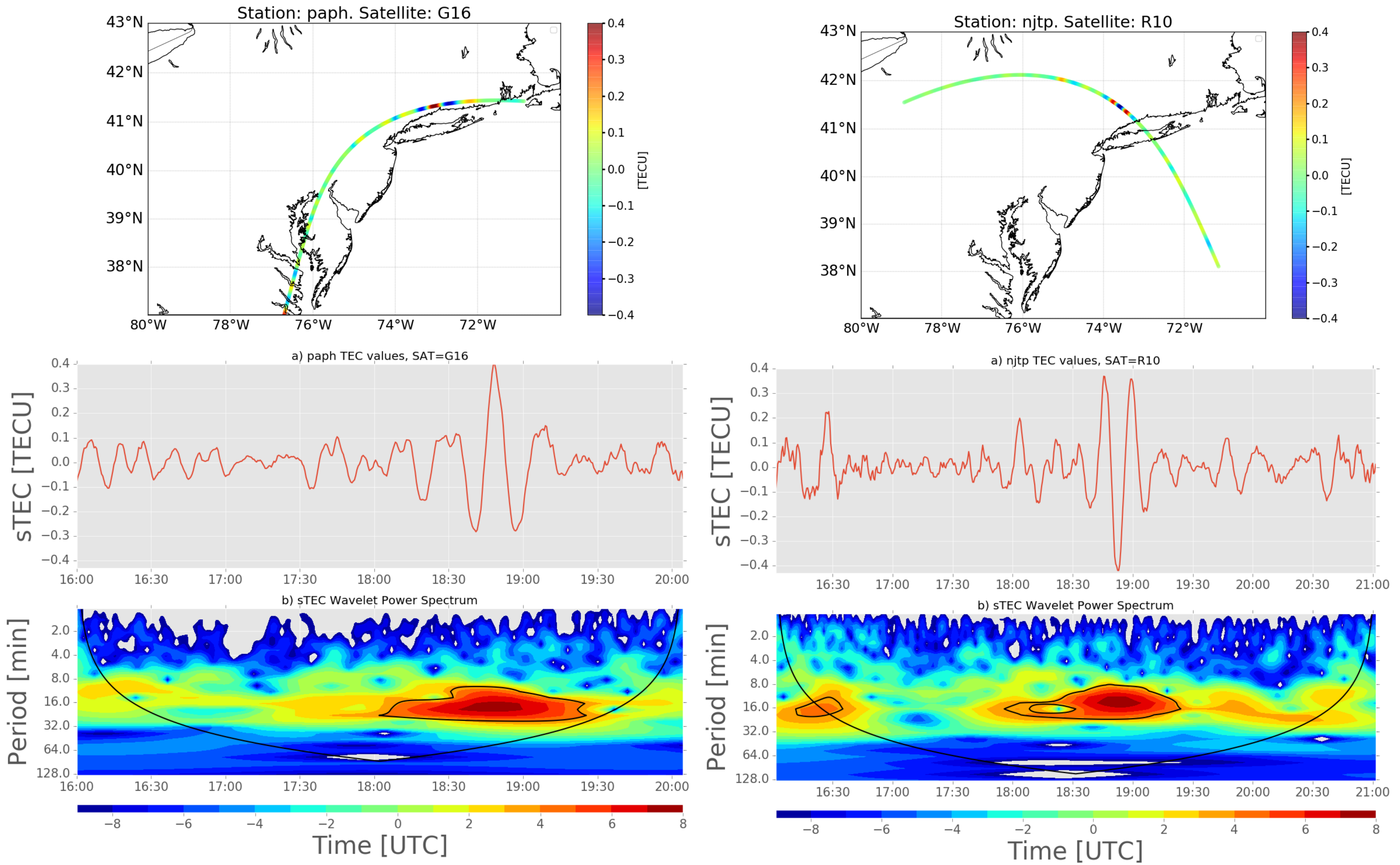


VARION Results



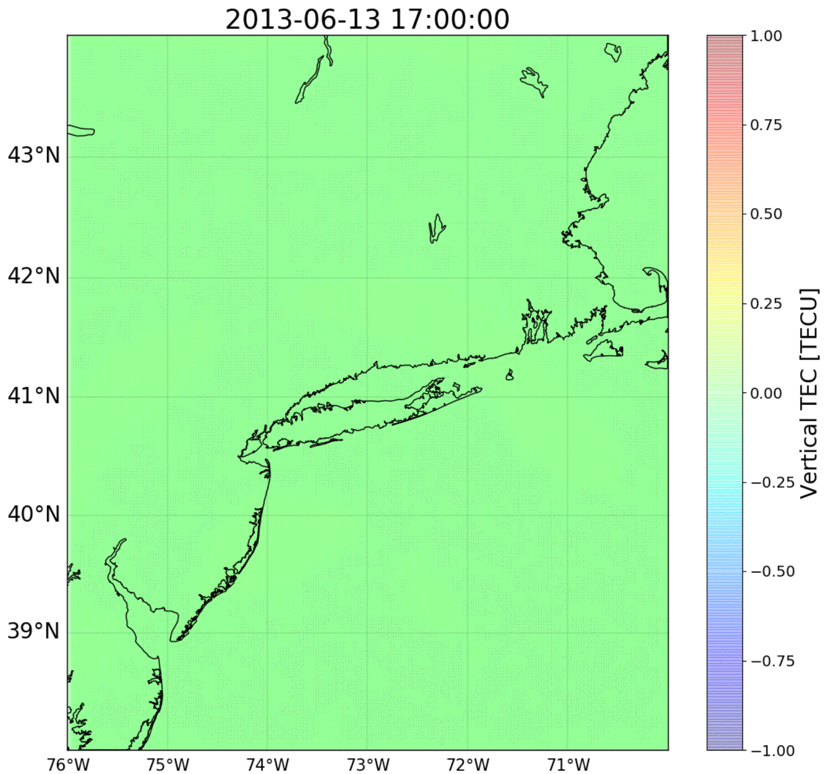
TIDs detected during the meteotsunami event

Wavelet Analysis

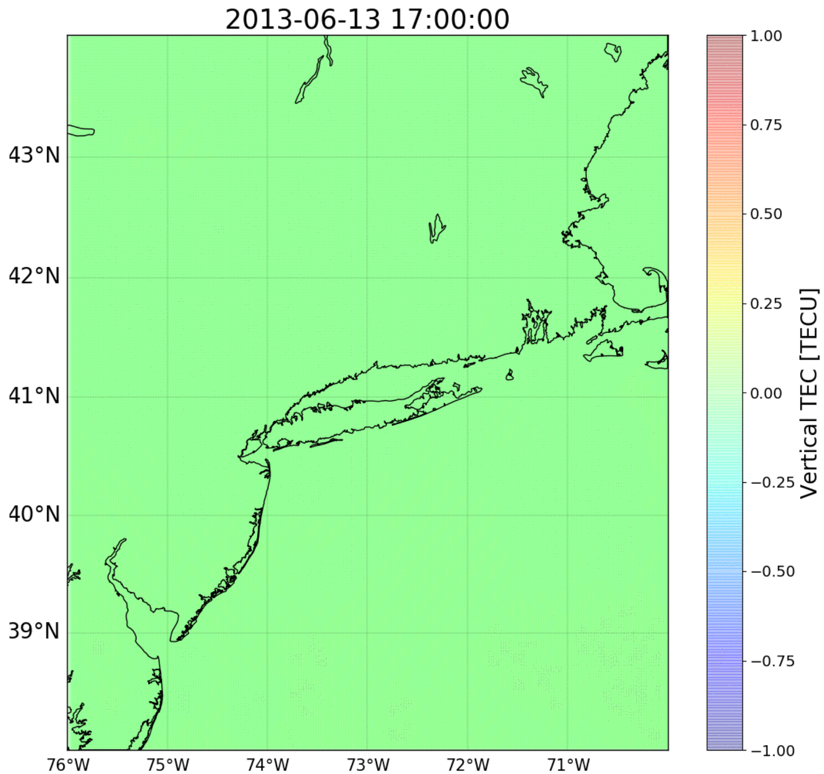


WP-GITM Simulations

- **Tsunami Speed = 30 m/s**



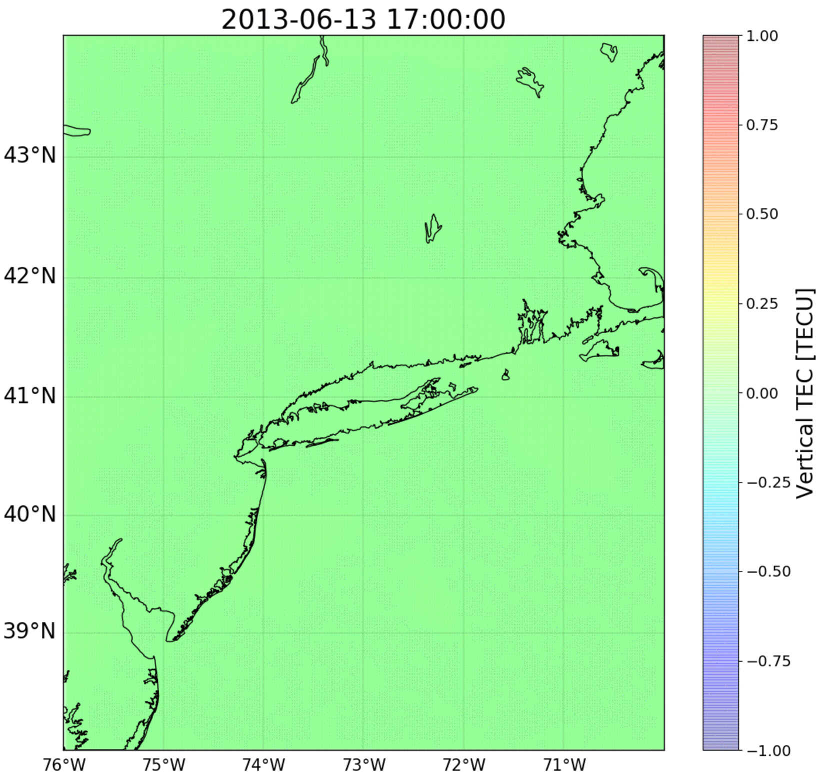
- **Tsunami Speed = 250 m/s**



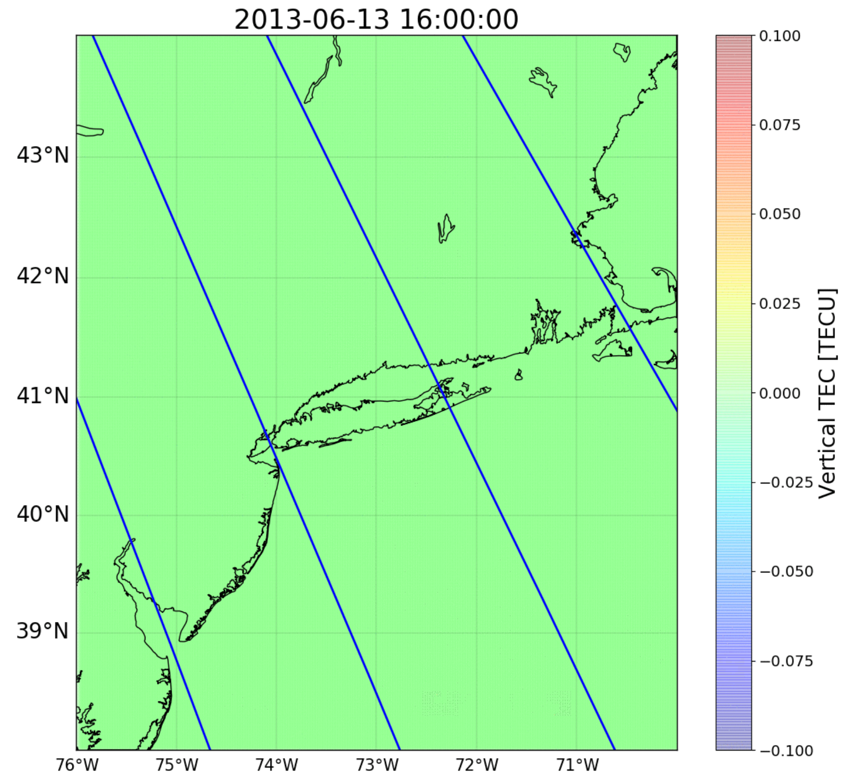
Tsunami Speed: key parameter for the ocean/ionosphere coupling

WP-GITM Simulations

- Tsunami Speed = 30 m/s
- **Wave Direction = 120˚ East**



- Tsunami Speed = 30 m/s
- **Wave Direction = 45˚ East**



Wave Direction: key parameter for the ocean/ionosphere coupling

Conclusions and Prospects

Conclusions

- **Ionospheric response** was a combination of effects: **Mesoscale Convective System (MCS) + Meteotsunami**
- **Tsunami speed** is a key parameter for WP-GITM to describe the **coupling ocean/ionosphere**
- **Wave direction** is an important parameter for WP-GITM because of the **Earth's geomagnetic field lines**

Future Work

- Add more high-quality ionospheric observation using **GEO** and **MEO satellites**
- Perform a **sensitivity analysis** with WP-GITM to better characterize the **ionospheric response** with different **parameters**

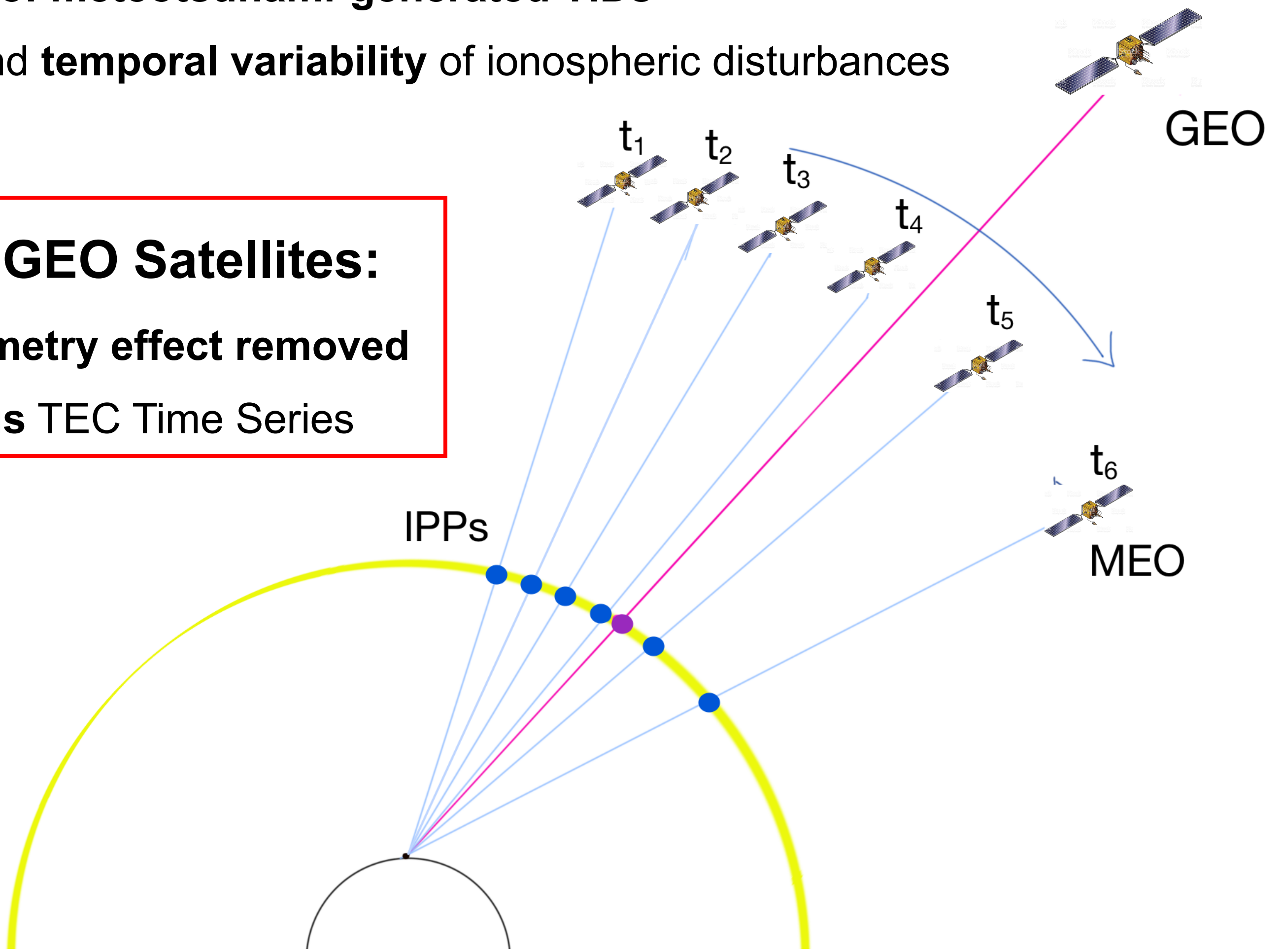
Future Work

Motivation for using geostationary (GEO) satellite to:

- **Improve detection of meteotsunami-generated TIDs**
- **Separate spatial** and **temporal variability** of ionospheric disturbances

Advantages of using GEO Satellites:

- GNSS satellite **geometry effect removed**
- Provides **continuous** TEC Time Series



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Thanks for your attention